CALIFORNIA'S COOPERATIVE SNOW SURVEYS PROGRAM

BY

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ABSTRACT

The California Cooperative Snow Surveys Program began in 1929 and has continued since as a very important water management and regulation tool in the State. Each spring, about 50 agencies pool their efforts in collecting snow data at nearly 270 snow courses in the mountains. The snowpack information, along with precipitation and antecedent river runoff data, are used by Department of Water Resources staff experts to develop forecasts of expected snowmelt runoff and total water year runoff on the major rivers. These forecasts are used by water agencies, farmers, cities, hydroelectric facility operators, and regulators to manage the available water supply for the benefit of the State's farm, urban, and environmental interests.

Runoff forecasts are made systematically, based on historical regression relationships between the volume of April through July runoff and the snow water content, precipitation, and runoff in preceding months. The official monthly forecasts depend quite heavily on manual snow course data whereas periodic updates after major storms rely on daily or even hourly information from about 115 remote snow sensors (snow pillows) which report in by radio. Although most people are just interested in the median future outlook, a range of forecasts from 90 percent sure to 10 percent sure are also provided on most rivers.

This paper will discuss the history, the methodology, and how the various interests make use of the forecasts produced by the Cooperative Snow Surveys program.

INTRODUCTION

The snowpack of the Sierra Nevada furnishes around 35 percent of California's usable water supply, about 18 billion m^3 (15 million acre-feet) of runoff during the April through July late spring and early summer period. Without this natural regulation of winter precipitation which the State is blessed with, much more reservoir storage would be needed to meet our summer peaking irrigation water demands.

Already over 100 years ago, it was recognized that there was a general relationship between the size of snowpack and spring and summer runoff. The initial impetus for systematic observations and forecasts came from Lake Tahoe, a high elevation lake (1900 m with an area of nearly 500 km^2) between California and Nevada, as an attempt to settle the water war over the lake level.

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There is a small dam at the outlet of Lake Tahoe into the Truckee River. Currently the lake is operated over a 1.9 m (6.1 feet) range. The irrigation and power interests wanted to keep the lake as high as possible. Sometimes melting snow pushed it up to where lakeside homes were endangered. Pioneering snow survey methodology developed by Dr. James Church, of the University of Nevada, provided much better estimates of the lake's spring rise from snowmelt and set a precedent for cooperation amongst interested parties. Church developed a prototype of the snow samplers now used around the world. The Mt. Rose snow survey course started by Dr. Church has been measured since 1910 and is the oldest, although several other courses in the Tahoe – Truckee drainage catchment go back to around 1915.

As the successful use of snow surveys in the forecasting of runoff became known, several water agencies began independent snow survey programs. After a few years, these agencies, and the State of California, recognized both the inherent value that such information could have for water users throughout the State and the need for centralized coordination of the snow survey program. Following some sporadic attempts at statewide involvement, in 1929 the State Legislature established a statewide program that has continued to this day. The Legislature, after consultation with major water interests, determined that the Division of Water Resources (now the Department of Water Resources) would be the coordinator of the "California Cooperative Snow Surveys Program" and so directed in Section 128 of the Water Code. The language is quite interesting: it is described as " the annual forecast of seasonal water crop". In 1959, Harlowe M. Stafford, engineer with the California Department of Water Resources, wrote a pretty thorough article on the history of snow surveying in the west (1959).

Today in California more than 50 State, national, and private agencies pool their efforts in collecting snow data. About 270 snow courses are sampled each winter with some of the original courses, established more than 80 years ago by Dr. Church, still in use.

The snowpack information is used to predict how much spring runoff to expect. The water supply forecasts are vital for planning and management of the State's water resource systems -- to benefit all Californians. Figure 1 shows the location of the major river basins on which the forecasts are made, along with a sample of such forecasts from one of last year's reports.

COLLECTING THE DATA

Runoff forecasts are made systematically based on historical regression relationships between the volume of April through July runoff and the snow water content, precipitation and runoff in preceding months. These are the primary hydrologic variables. Because regression relationships are used, it is very important that the snowpack water measurements are made consistently from year to year and that the snow courses are maintained in the same condition, especially as to exposure. (Growing trees, for example, can change the patterns of snow accumulation.)

Snow courses generally consist of 7 to 10 sample points, where snow depth and the weight of water content are measured with aluminum tubes. The tube diameter is such that the weight converts directly to depth of water (inches in our case). Surveyors carefully measure off distances from a reference end point so that all samples are taken in approximately the same place each time. The aluminum tube is threaded in sections of about ¾ meter and sections can be added as necessary to penetrate the entire pack. At some of the heaviest courses, the average water content is around 2.0 meters and the corresponding depth 4 to 5 meters. In a really wet year, depths can reach 8 meters. The average overall of all courses is more like 2 meters of depth and ¾ meter of water content. All the point measurements on a course are averaged to give a single value of depth and water content for the course. The density is determined as the water content divided by the depth and assists in quality control. The Department puts forth considerable effort in standardizing snow course data collection. This includes training in the field with cooperating agencies and checking the arithmetic on nearly 1,000 snow notes (pages of field data) each year. The four part Figure 2 may help in visualizing what is involved in sampling.

The basic premise of the Cooperative Snow Surveys program is that the various water agencies will take the snow measurements, or reimburse the State or others who do. The State will coordinate the sampling program, collect other parameter data much as precipitation and calculated unimpaired (natural) runoff, then make the runoff forecasts and issue them. In more recent decades the snow data includes that measured automatically by remote telemetered gages (snow sensors or snow pillows) and the same principles apply.

A sample of the forecasts from May 1 of last year is shown on Figure 1 (DWR 2003), the location map of the major river basins. The forecasts are published in a short 16 page report summarizing current water conditions which is prepared four times a year, soon after February 1, March 1, April 1, and May 1. These are the official forecasts which are used by water system operators and also used to determine a host of environmental standards, such as, stream fishery flows, water deliveries and water rights conditions. Almost all of the regulatory requirements are based on median future assumptions. For Central Valley rivers, the report contains seasonal volume forecasts and a monthly distribution of the median forecast. Forecasters also provide a range of runoff amounts in the report, from 90 percent sure (dry) to 10 percent (wet). Intermediate forecasts are made during the season every week or two and after major storms to help guide reservoir operators. The primary source of updated snow data is the automatic snow sensor network of 115 or so snow pillows. The more reliable manual course measurements are still the backbone of the primary first of the month runoff forecasts.

The forecasts for most rivers is in two parts: the amount expected during the April through July period and the total for the entire water year, October through September. Runoff during the tail end of the season, August and September, is quite tightly correlated with April through July runoff and that segment of the water year forecast is based on those historical correlations. For the first portion of the water year, October through March, forecasters rely upon runoff to the date of forecast and precipitation accumulations thus far to estimate the remaining months of the winter season (for example March runoff in the March 1 forecast). By April 1, of course, this runoff is known. River basin forecasts are checked with those of adjoining basins to ensure fits within the historical ranges between basins. It is not uncommon to have a wetness gradient from one end of the range to the other and these show up in the interbasin comparisons.

USES OF THE FORECASTS

The primary users are still the water project operators and their customers. Environmental agencies use the forecasts too to guide their operations – especially anadromous fishery interests. The forecasts have high credibility and are used by regulators to set river water quality and flow standards. The State is regarded as an unbiased party and its forecasts are trusted. The same would not be true for individual project operators (many of whom do make their own forecasts as well). The general approach is for more stringent criteria and larger flows to be required in wet years with relaxation in drier years when there are water shortages. The major flow and quality requirements in the Sacramento San Joaquin River Delta are keyed to 5 different categories of wetness. These criteria require on average around 6 billion m^3 per year (5 million acre-feet) per year. The May 1 forecast is usually within 10 percent of actual runoff in all but years with unusual May weather. We do have an advantage over many other regions of the world in that our summers are dry, so the weather variable after May 1 (and often after April 1) is not large. But there are exceptions, such as May of 1996, which had a mid month flood producing storm. Accurate forecasting is also more difficult in years of thin snowpacks where losses can deplete a bigger percentage of the snowpack.

Each fall, the staff and cooperating agency staff, have an annual meeting to review how operations went the previous season, to hear about new developments, and to renew contacts. These annual meeting are an important element of maintaining the cooperative program, which has now been in operation over 70 years. Currently the California State budget has had a deficit which has required some cutbacks in the program, especially forecasting procedure development and updating. But we think the value of the program is recognized by all California water interests.

SUMMARY

We have estimated that the value of water produced by the major watersheds being forecasted is in the order of 4 billion U.S. dollars per year and the hydroelectric power about 1 billion dollars. We believe the value of the forecasting program probably is in the range of 3 to 5 percent of these benefits, or from 150 to 250 million dollars per year. The total cost by all cooperators is on the order of 4 million dollars, primarily for data collection. One could argue about the value of water supply forecasting, but it is evident that even a 1 percent improvement at 50 million dollars could yield a great benefit cost ratio. Because of the great and increasing value in properly managing our water resources, the future of the basic California snow surveys program seems assured.

REFERENCES

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Department of Water Resources
California Cooperative Snow Surveys
Forecast of April through July Unimpaired Runoff
in percent of historical average
as of May 1, 2003

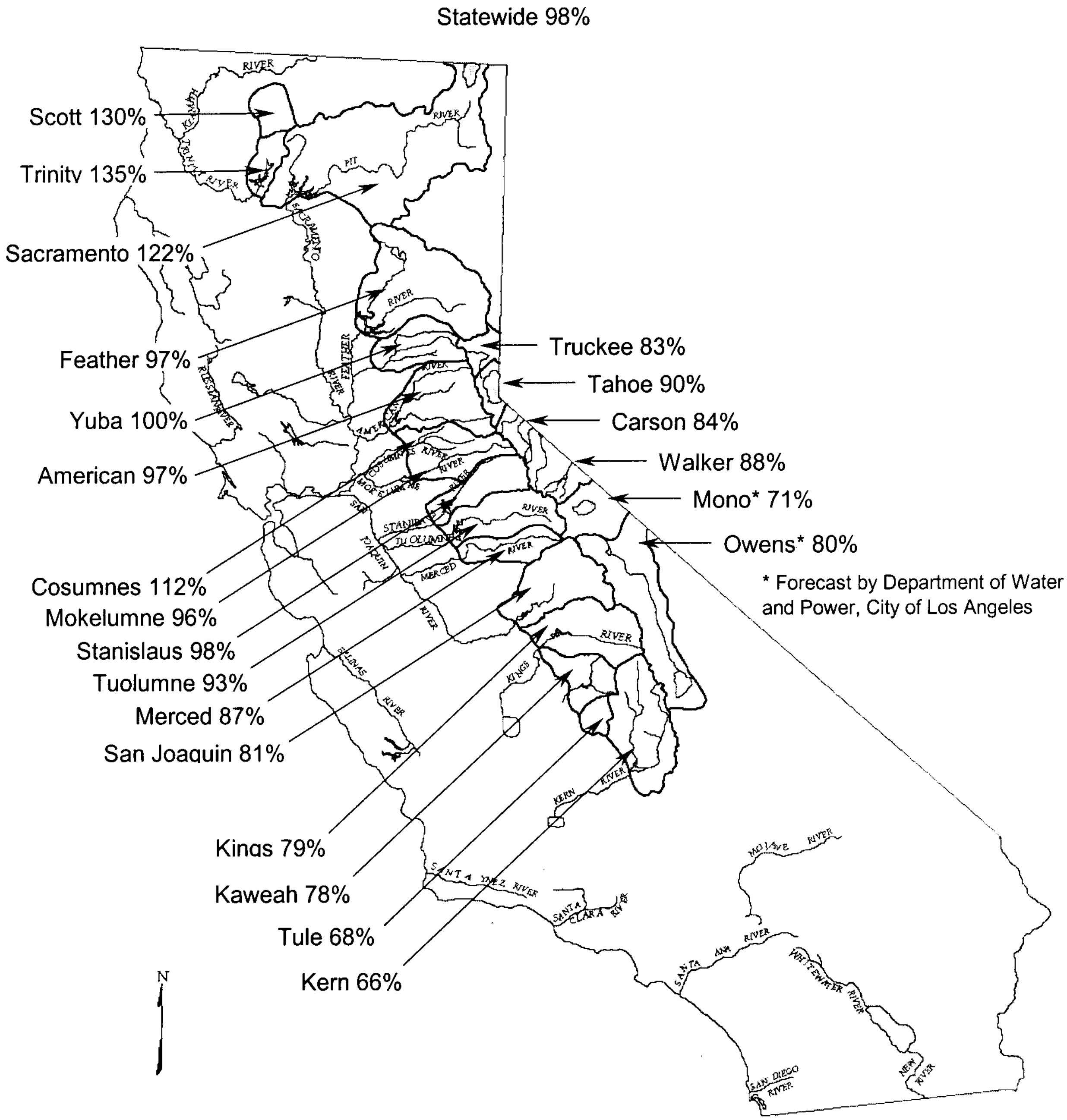

Figure 1. Location map and sample of forecasts

Figure 2a. Snow surveyor with measuring tube.

Figure 2b. Measuring tube pushed into snow. Man at the right holding the scale to measure weight of tube when extracted.

Figure 2c. A close up of measuring tube.

Figure 2d. The weight of the tube and core are recorded. The water content of the snowpack is the difference between the weight of the empty tube and that of the tube and snow core.